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MEDIUM EXPLORER (MIDEX) PROGRAM

MIDEX Safety, Reliability & Quality Assurance Requirements

January 18, 2001

Approved by: Prepared by:

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Anthony Comberiate   Richard Claffy
Explorer Program Manager   Mission Assurance Manager

NASA Goddard Space Flight Center

Greenbelt, Maryland

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MIDEX Safety, Reliability & Quality Assurance Requirements

<u>Overview</u>

Reliability considerations for the MIDEX Program are bounded by programmatic demands for scientific excellence, low cost, and rapid development. As a result, systems are expected to be predominantly non-redundant or "single string." However, redundancy is encouraged where appropriate and where resources allow.

The safety, reliability and quality assurance requirements for the MIDEX Program will be structured to accept the increased risk that is inherent in a predominately non-redundant system. Good quality parts and materials, a limited reliability and quality program, and significant reliance on the test program will be key factors in balancing reliability goals against program cost and complexity constraints.

The Proposer has responsibility and control over development of the instrument(s), the spacecraft, and, generally, the selection of the launch vehicle. Only limited support is planned by NASA, with emphasis on those activities that contribute most to product reliability and integrity. Deliverable documentation is reduced, provided the Proposer maintains adequate internal records that demonstrate traceability when needed.

The safety, reliability and quality assurance requirements for the MIDEX Program recognize a wide variation in complexity, size, and technology of proposed instruments and spacecraft; these all can affect program risk and costs. The requirements recognize that there are significant differences in the availability to investigators of facilities, skills, and supporting capabilities. The safety, reliability and quality assurance program ensures that hardware and software are designed, manufactured, and tested to flight standards, and that drawing and specification requirements are met. Guidelines and requirements for conducting an appropriate safety, reliability and quality assurance program are contained in this document. Part 1 contains MIDEX Assurance Requirements (MAR). It is expected that these requirements will be incorporated into the Proposer's contract documents. Part 2 contains MIDEX Assurance Guidelines (MAG). These guidelines are provided for the purpose of describing the things that experience has shown result in a reliable product. They are highly recommended but are not required.

The Proposer should refer to the MAR and MAG in developing his safety, reliability and quality assurance approach and realistically addressing the costs associated with these tasks. During the definition phase of the mission the specific implementation details of the Proposer's safety, reliability and quality assurance program will be negotiated. The quality program shall be modeled after ANSI/ASQC Q9001-1994, "Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing".

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As part of the proposal submitted in response to an AO, a brief two-three page description of the proposed approach to safety, reliability and quality assurance is required. The description should reflect the Proposer's understanding of, and approach to, implementing the safety, reliability and quality assurance requirements/guidelines contained in the MAR/MAG. The description should also provide the basis for the safety, reliability and quality assurance costs contained in the proposal. The Proposer is encouraged to make maximum use of existing practices and procedures in developing and implementing the safety, reliability and quality assurance program. For requirements that are not fully applicable, because of a particular aspect of the instrument or mission, the Proposer should provide appropriate rationale. The Proposer may also offer an alternate method of meeting the intent of a requirement when such a method is better aligned with the manner in which the total work is to be accomplished. The Proposer must describe the plans for maintaining adequate internal documentation for all safety, reliability and quality assurance activities and for providing NASA with essential deliverable documentation.

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Part 1

MIDEX Assurance Requirements

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MEDIUM EXPLORER (MIDEX) PROGRAM

MIDEX ASSURANCE REQUIREMENTS

Rev C

January 18, 2001

Approved by: **Prepared by:**

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Anthony Comberiate   **Richard Claffy**
Explorer Program Manager   **Mission Assurance Manager**

The purpose of this document is to concisely present the safety and assurance requirements that are necessary for the MIDEX Project. These requirements are intended to be incorporated into MIDEX developer contract documents.

NASA Goddard Space Flight Center

Greenbelt, Maryland

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1.0 OVERVIEW

The developer shall plan and implement an organized safety, reliability and quality assurance (SR&QA) program for flight hardware, software and ground support equipment. The developer shall support and participate with the Explorer Project at GSFC in validating and periodically reviewing the SR&QA program. This document presents a concise statement of MIDEX minimum requirements. Additional information can be found in GSFC-410-MIDEX-001, "MIDEX Assurance Guidelines" which is contained in Part 2 of this document.

In accordance with NASA Headquarters policies for Medium-class Explorers, a payload classification per NMI 8010.1A is not being issued for MIDEX. This will permit tailoring of the SR&QA requirements in accordance with the ISO 9001 series standards, supplemented by mission assurance guidelines and requirements appropriate for the level of risk for a program of this scale. The mission assurance program should augment the project team's overall risk management process. A Continuous Risk Management (CRM) methodology must be used that identifies existing or emergent technical and programmatic risks, statuses them, evaluates mitigation efforts, and retires them or carries residual risks forward.

Under this AO, PI teams are free to propose Missions of Opportunity, investigations that involve missions not funded or managed by OSS. GSFC recognizes that in this circumstance, the actual scope of work performed under these requirements by the PI institution may differ significantly from that of complete and independent PI missions. Therefore, the requirements in this document apply, but only within the work scope that is under direct control of the PI institution. Limited applicability is based on the necessity that host missions maintain their own traditional systems for managing Science, Engineering, Safety, Reliability, & Quality Assurance requirements. Furthermore it is reinforced by the fact that the PI institution will be required by the host to abide by those requirements and to physically and functionally match all provided interfaces. No limited applicability is permitted for system safety, range safety, or personnel safety requirements.

2.0 QUALITY ASSURANCE

2.1 Quality System

During Phase B the developer shall define and implement a quality system based on ANSI/ASQC Q9001-1994 that properly encompasses MIDEX flight hardware, software, and Ground Support Equipment. The quality manual, as required by this standard, shall be provided for GSFC review during Phase B. An agreement between the Principal Investigator and the Explorer Program Office on the quality assurance, reviews, safety, design assurance and verification system to be implemented will be required prior to the confirmation of the mission.

2.2 Workmanship

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The following commercial, or NASA, workmanship standards shall be used for MIDEX:

- NASA-STD-8739.3:   Requirements for Soldered Electrical Connections

- NASA-STD-8739.4:   Crimping, Interconnecting Cables, Harness, and Wiring

- NHB 5300.4 (3H):   Requirements for Crimping and Wire Wrap

- NHB 5300.4 (3I):   Requirements for Printed Wiring Boards

- NHB 5300.4 (3J):   Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies

- NHB 5300.4 (3K):   Design Requirements for Rigid Printed Wiring Boards and Assemblies

- NHB 5300.4 (3L):   Requirements for Electrostatic Discharge Control (Excluding electrically initiated explosive devices)

  Soldering of electrical connections: ANSI/J-STD-001 (High Reliability Class) and the applicable associated standards ANSI/J-STD-002 through -006. [NASA alternative - NHB 5300.4 (3A-2)]

  Cable, harness, and wiring interconnections: NHB 5300.4(3G)

  Crimping: NHB 5300.4(3H)

  Conformal coating and staking: NHB 5300.4(3J)

  Printed wiring board design: IPC-D-275 [NASA alternative - NHB 5300.4(3K)]

  ESD control: EIA-625 [NASA alternative - NHB 5300.4 (3L)]

The developer shall provide printed wiring board coupons to GSFC, or to a GSFC approved laboratory for evaluation. Approval shall be obtained prior to population of printed wiring boards.

2.3   Mission assurance Audits and Reporting

Assurance Status Reports will be part of the regular, monthly reporting by the Principal Investigator to the Explorer Program Office and will summarize the status of all assurance

activities and report on any discrepancies (including corrective actions) that could affect the performance of the investigation.

During all phases of the mission, NASA must be able to assess the reliability of the mission and understand how the Principal Investigator is resolving problems. In order to do this, the Principal Investigator is required to document and report failures to the Explorer Program Office beginning with initial power-up of any flight component or assembly (including critical GSE). Reporting is to continue until successful closure by the Principal Investigator's Failure Review Board (FRB).

In order to ensure that the quality system is working the way it is intended, the Principal Investigator is required to plan and conduct audits of his/her internal mission assurance systems and those of his/her subcontractors and suppliers, examining documentation (processes, procedures, analyses, reports, etc.), operations and products. The Principal Investigator is required to generate and maintain a report for each audit. A summary of all audit findings should be included in the monthly report.

2.3 Failure Reporting

The developer shall report failures to the Explorer Project at GSFC beginning with tests at the major component, subsystem, or instrument level. Reporting shall continue through successful closure with the Project Failure Review Board.

3.0 —REVIEWS

The Principal Investigator is encouraged to focus resources from the beginning and throughout the mission development phase on engineering working-level reviews (peer reviews) to identify and resolve concerns prior to formal, system level reviews. The Principal Investigator's quality system is to track and close-out all actions items identified during these peer reviews to ensure that issues are resolved promptly at the lowest levels and before system level reviews. A list of action items/closures for each peer review should be maintained by the Principal Investigator's quality system and made available during system level reviews. Any open action items from any peer reviews should be addressed at the system level reviews.

Peer Review is defined as a detailed independent engineering design review focused at the Subsystem and box level, conducted informally with recognized internal or external experts having current detailed knowledge of the design specialties associated with the item under review. Primary design documentation, such as drawings, schematics, wiring diagrams, and analyses are the review vehicles. Its purpose is to substantiate a detailed understanding of the design's ability to meet all of its performance and interface requirements, to surface correctable problems early, and to ensure best known practices are used that enhance robustness by avoiding known or predictable problems. Timely, accurate insight, through action item

documentation and follow-up activities, is vital to the process. For each review a written record must be kept of time, place, and attendees.

Upon request, the Explorer Program Office will supply technical expertise as required for participation in the areas undergoing peer reviews.

Unlike the many informal engineering peer reviews that are required during the project life cycles, there are two semiformal reviews focusing on requirements and the mission concept. In addition, six formal system level reviews are required to concentrate on 1) critical systems; and 2) end-to-end mission level technical, safety, reliability, flight operations, ground operations, and programmatic issues. If warranted, additional formal reviews may be required for unusually complex areas such as safety and/or flight and ground operations. The following represent the semiformal and formal reviews expected under this program:

- Requirements Review (Semiformal)

- Concept Review (Semiformal)

- Preliminary Design Review (Formal)

- Critical Design Review (Formal)

- Pre-Environmental Review (Formal)

- Pre-Ship Review (Formal)

- Operations Readiness Review (Formal)

- Flight Readiness Review (Formal)

Semiformal and formal reviews are to be conducted by a review panel named by the GSFC Systems Management Office and the PI, which is independent of the development team. The Explorer Program Office must be invited to attend all reviews. Copies of the presentation materials must be provided to the Explorer Program Office for information. Formal reviews are to be chaired by GSFC's Systems Management Office. It is the Principal Investigator's responsibility to address all concerns and action items identified during these reviews.

Included in the above list of formal and semiformal reviews is the Operations Readiness Review (ORR). This review shall be held with GSFC to assess readiness, and to document the final details of the approach agreed to be used for flight operations. The result of this review shall be reported at the Mission Readiness Review. The mission operations agreement reached at the ORR cannot be changed without NASA concurrence.

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Independent NASA reviews, including Red Team review activity, and a Confirmation Review as described in the AO, will also be conducted. (Independent balloon mission reviews will be conducted as described in the Balloon SR & QA appendix. A more streamlined design review process is envisioned for balloon missions that are confirmed at significantly lower budget levels and/or which allow multiple flight opportunities. The Explorer Program Office, PI, and Systems Management Office will agree upon Details of such reviews.) These reviews will be coordinated with the Principal Investigator so that they can coincide with other reviews when possible. It is the Principal Investigator's responsibility to address all concerns and action items identified during these reviews.

Red Team reviews have recently been commissioned for all NASA/GSFC missions in response to NASA/HQ direction to assess across all flight programs the health and thoroughness of institutional internal design review processes. The Red Team is a standing body of technical experts who operate under Center Director authority in accordance with NASA/HQ direction. They utilize standardized criteria to independently and objectively rate overall mission risk level and officially report it to the Center Director via Program Management Council. Results of these reviews are considered a necessary basis for proceeding to launch operations.

3.0 REVIEWS

The MIDEX program office philosophy is to focus resources early and throughout the program on engineering working level reviews to identify and resolve concerns before these issues reach formal, high level system reviews. The developer is responsible for conducting these engineering peer reviews. Upon request through the Explorers Project, GSFC will provide technical expertise as required for participation in the areas undergoing detailed engineering review.

The formal system level reviews will concentrate on critical system and end to end mission level technical and programmatic issues. There will be four formal system level reviews:

? Confirmation Review (in Phase B)
? Pre Environmental Review (in Phase C/D)
? Pre Ship Review (in Phase C/D)
? Flight Readiness Review (in Phase C/D)

These formal reviews will be chaired by the GSFC Office of Flight Assurance Systems Review Office (SRO), Code 301 at GSFC. Scheduling of these reviews will be coordinated with the MIDEX Project. The review chairman, in concert with the Project and other Directorates, appoints independent key technical experts as review team members. Every effort will be made to maintain the chairman and the key technical experts for the duration of the Project. Other experts will be added and/or deleted from the review team according to the technical needs and phases of the Project. Mission and flight operations requirements issues will be presented at the above reviews, unless a formal independent review is warranted because of the complexity of the flight and ground interfaces.

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3.1 Definition Phase B Reviews

Phase B formally begins with the signed contract agreement for the mission and ends with formal confirmation for the mission by NASA headquarters following a Confirmation Review (CONR). It is expected that during Phase B the mission team will hold at least two informal reviews prior to the CONR. These reviews are the Requirements Review (RR) and the Concept Review (CR).

The purpose of the RR is to:

? create the relationship necessary for successful and effective implementation of the mission
? ensure in depth understanding of requirements among all cognizant organizations
? confirm technical data for release of long lead procurements

The purpose of the CR is to:

? evaluate the mature end to end mission concept to ensure minimum science requirements are met
? complete science, technical, cost, schedule tradeoffs to verify mission resources
? evaluate team performance

The RR and CR are the responsibility of the mission team, and will be co-chaired by the Proposer and the Explorer's Project Mission Manager (as opposed to a formal review chaired by Code 300).

The CONR represents the review leading to the closure of Phase B. At this point the mission design is considered complete and final. Prior to this review, in depth peer reviews will have been organized and held by the lead subsystem engineers. The resultant technical, scientific and programmatic plans will be presented at the CONR.

The purpose of the CONR is to review:

? final design, fabrication and test plans for each subsystem
? final interface control documents
? mission integration and verification plans
? complete programmatic plan through launch
? requirements flow down traceability
? risk identification and mitigation plans
? cost, schedule and resource plans

NASA Headquarters personnel will participate in this review and prepare their report based on their independent verification of the end to end mission implementation plan. Following the CONR, a presentation will be made to the NASA HQ program office requesting confirmation to proceed to Phase C/D.

3.2 Phase C/D Reviews

Phase C/D starts with the confirmation of the mission and a signed contractual agreement for the development, launch and validation in orbit (typically within 30 days after launch) of the mission. Throughout Phase C/D, it is expected that the informal engineering reviews will continue. Topics covered in these peer reviews will include (also see section 3.3 herein):

? interface control design verification

? parts and materials review

? analysis and studies

? safety issues

? risk assessment, resolution and contingency plans

? procurements

? confirmation of technology items

? hardware and software configuration management

? detailed cost, schedule and resource availability

? manufacturability and testability

The Pre-Environmental Review (PER) will assess the readiness of the flight hardware, software and required environmental test facilities to begin acceptance testing. The PER will also cover:

? design changes since CONR

? status of nonconformances

? test documentation (plans, procedure, waivers) and facilities readiness

? hardware and software configuration

? mission operations status

The PER will be held prior to the full system integration and functional test in preparation for environmental testing.

The Pre-Ship Review (PSR) will verify that testing has been completed with no unacceptable open issues and to evaluate the readiness of the hardware and software for flight. The PSR will also cover:

? determination of completion of testing flight hardware and software

? verification and documentation of hardware and software configuration

? identification of outstanding safety risks

? disposition of waivers, deviations, open issues

? compatibility of spacecraft and ground support equipment

? orbital operations plans

The PSR will be held immediately prior to the shipment of the flight hardware to the installation site and prior to the shipment of the observatory to the launch site.

The Flight Readiness Review (FRR) will be conducted at the launch facility to verify overall readiness of flight hardware and software, and ground and launch support resources to achieve the mission flight objectives.

3.3 Peer Reviews

Engineering peer reviews will occur during all phases of the project life cycle. These reviews are expected to be the most detailed of the MIDEX reviews. It is the intent of the peer reviews that participants generate a detailed understanding of the component and subsystem designs' ability to meet higher level system and mission requirements. Effective peer reviews will enable significant streamlining of the content of higher level formal reviews described in section 3.1 and 3.2 herein. To promote continuity of the whole review program, invitations will be extended to the Systems Review Office to attend peer review sessions.

4.0 SAFETY

4.1 General

The PI is required to plan and implement a system safety program that identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of the mission development, launch, and operations. The program is to address hazards in the flight hardware, associated software, ground support equipment, and support facilities.

The NASA requirements translate into a series of specific scheduled deliverables, whose nomenclature, relative timing and process flows will differ depending on the selected launch method: Expendable Launch Vehicle (ELV); or the National Space Transportation System (NSTS); or Long Duration Balloons (LDB).   Paragraph 4.2 below cites the controlling requirements documentation for ELVs. Paragraph 4.3 cites the requirements that must be met for NSTS launched payloads. These documents are extremely detailed and NASA expects them to be implemented by the PI team to correctly fit each selected mission. To assist PI groups with their system safety cost planning efforts, process descriptions and typical processing flow diagrams, "Expendable Launch Vehicle (ELV) System Safety Milestones and Process Flow" and "National Space Transportation System (NSTS) System Safety Milestones and Process Flow" are available in the Explorer Program Library. Paragraph 4.4 cites the requirements that must be met for National Scientific Balloon Facility (NSBF) launched balloon payloads.

4.2 ELV Payload Requirements

The PI team's system safety program must meet the system safety requirements stated in the applicable launch range safety regulation. The top level governing documents are: 1) EWR 127-1, "Eastern and Western Range Safety Requirements"; or 2) RSM-93, "Range Safety Manual for Goddard Space Flight Center/Wallops Flight Facility".

4.3 NSTS Payload Requirements

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The PI team's system safety program must meet all Space Shuttle safety requirements imposed by the Johnson Space Center for NSTS payloads. The controlling safety documents are (NHB) 1700.7, "Safety Policy and Requirements for Payloads Using the Space Transportation System"; and (KHB) 1700.7, "STS Payload Ground Safety Handbook". The Space Shuttle Program typically requires 3 safety reviews. Proposers are advised that Space Shuttle safety requirements are particularly strict and may lead to unexpected design changes, additional test or analysis requirements, and associated cost increases. Therefore, higher contingency levels are recommended for Shuttle based missions

4.4 NSBF Requirements

The PI team's system safety program must meet the system safety requirements stated in documents "NASA Balloon Program National Scientific Balloon Facility Payload Safety Process" and "NASA Balloon Program National Scientific Balloon Facility Ground Safety Plan".

4.5 Ground Operations Procedure Approval

The PI is additionally required to submit, in accordance with an agreed to schedule, all ground operations procedures to be used at GSFC facilities, other NASA integration facilities, or the launch site, for review and approval by NASA. All hazardous operations, as well as the procedures to control them, are to be identified and highlighted. All launch site procedures are to comply with the applicable launch site safety regulations.

4.6 Documentation Availability

All of the ELV and NSTS safety documents cited in this AO can be obtained from the following websites:

http://www.pafb.af.mil/45sw/rangesafety/ewr97.htm

This is a direct link to the EWR 127-1 document.

http://jsc-web-pub.jsc.nasa.gov/psrp/

This is a direct link to the NSTS safety documents.

http://arioch.gsfc.nasa.gov/302/safety/

This site provides links to the requirements for the Wallops Flight Facility and the Pegasus Launch Vehicle.4.0   SAFETY

4.1 General

The hardware developer or mission contractor shall plan and implement a system safety program that accomplishes the following:

a. Identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of project development. The program shall address hazards in the flight hardware, associated software, ground support equipment, and support facilities.

b. Meets the system safety requirements stated in the applicable launch site safety regulation (EWRR 127-1 for the Eastern or Western Range) and the mission System Safety Implementation Plan (SSIP).

c. Meets all Space Shuttle safety requirements imposed by the Johnson Space Center for NSTS payloads (only when the proposed mission is a shuttle payload). The controlling safety documents are (NHB) 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System; and 45 SPW S-100/KHB 1700.7B, "STS Payload Ground Safety Handbook". The Space Shuttle Program typically requires three safety reviews. Proposers are advised that Space shuttle safety requirements are particularly strict and may lead to unexpected design changes, additional test or analysis requirements, and associated cost increases. Therefore, higher contingency levels are recommended for Shuttle based missions.

e.Meets the baseline industrial safety requirements of the institution, as well as any special contractually imposed mission unique obligations.

4.2 System Description and Safety Assessment Report

The hardware developer shall submit to the Explorer Project Safety Manager (PSM) a detailed description of the system down to the subsystem level, and a preliminary assessment of the system's compliance with the requirements of section 4.1.

Early in the design phase and continuing through the development effort, the hardware developer shall develop analyses identifying the ground operations hazards associated with the flight system, ground support equipment, and their interfaces. The hardware developer shall take measures to minimize each significant identified hazard. Because analysis does not lend itself to detecting some types of hazards (e.g., excessive electromagnetic radiation), it may be necessary to conduct tests to determine if certain hazards exist. All hazards affecting personnel, launch vehicle hardware, or the spacecraft shall be identified. The analysis shall be updated as the hardware progresses through the stages of design, fabrication, and test. Operations that may require analyses include handling, transportation, functional tests, and environmental tests. The results of the analysis shall be submitted as a Safety Assessment Report.

A synopsis of this on-going analysis, consistent with the maturity of the subsystem design, shall be part of each subsystem presentation at peer level and system level independent design reviews.

4.3 Procedure Approval

The hardware developer shall submit, in accordance with the contract schedule, all ground operations procedures to be used at GSFC facilities, other integration facility, or the launch site. All hazardous operations as well as the procedures to control them shall be identified and highlighted. All launch site procedures shall comply with the applicable launch site safety regulation.

4.4 Safety Noncompliance Requests

When a specific safety requirement cannot be met, the hardware developer shall submit to the PSM an associated safety noncompliance request that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in the applicable launch site safety regulation.

4.5 Support for Safety Working Group Meetings

The developer shall provide technical support to the Explorer Project Safety Manager for safety working group meetings, when necessary.

4.6 Safety Data Package

This requirement for a safety data package applies, as a formal deliverable to the PSM, only for those contractors with overall spacecraft or instrument safety responsibility.

The developer shall submit a safety data package consistent with the design maturity of the program at each of the phase C/D independent reviews, up to and including the Pre-shipment Review. The contents of each package shall be consistent with the requirements of the applicable launch vehicle and launch site.

The safety data package shall include, as a minimum, a detailed description of the payload design sufficient to support hazard analysis results, hazard analysis method, and other applicable safety related information.

The safety data package shall be submitted for approval in accordance with the milestones required by the applicable launch site safety regulation. It shall be consistent with the requirements of the applicable launch site. For example:

~~Eastern Range (ER) – A Missile Systems Pre-launch Safety Package (MSPSP) is required; the contents shall be consistent with the requirements of EWRR 127-1.~~

~~Western Range (WR) – A Safety Assessment Report (SAR) is required; the contents shall be consistent with the requirements of EWRR 127-1.~~

~~A list of all hazardous/toxic materials and associated material safety data sheets shall be prepared and included in the final MSPSP or SAR.~~

~~4.7 Launch Site Safety Plan~~

~~Contractors with overall safety responsibility shall submit a Payload Organization Launch Site Safety Plan consistent with the launch site requirements. It shall be submitted for approval in accordance with the milestones required by the applicable launch site safety regulation. The details of the plan will depend on the launch site selected.~~

5.0 DESIGN ASSURANCE

5.1 Parts

The developer shall implement an appropriate parts program. The program will be in place in time to effectively support the iterative design and selection processes.

All parts shall be selected and processed in accordance with GSFC 311-INST-001, "Instructions for EEE Parts Selection, Screening, and Qualification" for Grade 3 quality level. The developer shall control the selection, application, evaluation, and acceptance of all parts through a parts control board, or another documented system of parts control.

The developer shall maintain a EEE Parts Identification List and shall review proposed parts with GSFC.

5.2 Materials

The developer shall implement a Materials and Processes program beginning at Phase B. Proposed materials and processes shall be reviewed with the Explorer Project Materials Consultant. The developer shall maintain lists of these items (inorganics and metallics, polymerics, lubricants, and processes) and appropriate usage records.

5.3 Reliability

Early in the program's preliminary design phase, the Principal Investigator is required to identify specific reliability concerns and the steps being taken to mitigate them. As a minimum, the Principal Investigator is to conduct Failure Modes and Effects Analysis (FMEA) to a sufficient level of detail that mission critical failures are identified and dealt with effectively. Red Team reviewers will expect a demonstrated understanding of failure modes and effects down to the subsystem level of detail. Strong emphasis should be placed on critical single string design features. Appropriate use of the analytical tools and techniques collectively known as Probabilistic Risk Assessment (PRA) will significantly influence NASA's final judgement on the mission's overall reliability. These tools can include combinations of FMEA, Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Event Sequence Diagrams (ESD), Master Logic Diagrams (MLD), or Reliability Block Diagrams (RBD). PRA is a systematic, logical, comprehensive discipline that periodically blends use of these tools to quantify risk and maintain a current state of knowledge about risk of failure. Each individual tool provides a graphic representation of a complex thought process, which relates causes to outcomes, either from a deductive or inductive logic reference frame. Used together, the selected tools promote situational awareness regarding probabilities of unwanted consequences and the magnitudes of their possible impacts.

It is strongly recommended that the Principal Investigator accumulate several hundred hours of error-free operation of the integrated spacecraft and instrument(s) prior to the start of environmental testing.

5.3 Reliability

Early in the program's preliminary design process the developer shall identify specific reliability concerns and the steps being taken to mitigate them. The developer shall perform a Failure Mode Effect Analysis (FMEA) across the instrument and spacecraft interface. This analysis shall be available for review by the Explorers Project Reliability Consultant.

5.4 Contamination

The Principal Investigator is required to plan and implement a contamination control program consistent with the requirements of the mission. The plan should address all aspects of contamination control throughout the mission, including transportation and launch site processing. The contamination control plan should be made available to the Explorer Program Office if requested.

5.5 Software

The developer shall employ a structured program for the development of software. The program shall address appropriate development life cycle phases such as: requirements analysis, design, code and unit test, integration and build test, performance verification, and maintenance. Code produced shall be structured, error-free, and maintainable.

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During the preliminary design process, the developer shall establish and document software requirements and any appropriate external interface specifications and user guides.

The developer shall participate in a program of internal and external software reviews to validate software requirements, design, operating characteristics, and external interface requirements.

Software related anomalies on several recent NASA missions have given rise to new Agency level policy about software Independent Verification and Validation (IV&V). As a result of this new emphasis, all new NASA/GSFC missions will be required to discuss with GSFC IV&V advisors the ground and flight software development effort envisioned for the mission. The purpose of these discussions is to compare to the planned effort a set of standardized criteria now under development for determining the extent, if any, of IV&V that will be required for each mission. The official contact person for IV&V matters is William Jackson, phone 304-367-8215 or email <Jackson @ orion.ivv.nasa.gov>.

6.0   VERIFICATION

The Principal Investigator is required to conduct a verification program to ensure that the spacecraft and instrument(s) meet the specific mission requirements. It is recommended that the Principal Investigator use the Goddard Space Flight Center's General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components (GEVS-SE), available from the Explorer Program Office, as a tool and a model to prepare the mission verification plan and specification. Refer to the Balloon SR & QA appendix and the "Long Duration Balloon Opportunities" documents available in the Explorer Program Library to assist with verification planning for LDB missions.

The Principal Investigator is required to prepare and submit adequate verification documentation including a verification matrix, environmental test matrix and verification procedures to the Explorer Program Office for review. The ability to assemble complete test histories from detailed verification records has been proven necessary during recent Red Team activities, and has been shown to be supportive of the PRA process.

7.0 INDEPENDENT MISSION OPERATIONS REQUIREMENTS

Missions being operated by the PI independent of NASA must meet the following additional requirements. After on-orbit checkout, incident reports must be provided to the GSFC Space Science Mission Operations (SSMO) Project in accordance with "GSFC Flight Program Incident Reporting System Guidelines". Weekly orbital status summary reports shall be provided to SSMO. It is the PI institution's responsibility to contractually ensure the availability of spacecraft developer support of anomaly resolution efforts during the mission's operational phase. Structured management approaches to risk management and orbital mission

configuration control must be in place during the operational phase. An annual mission risk assessment status report shall be provided to SSMO.

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Guidance for Proposers of Balloon Missions, Regarding Tailoring of the MIDEX Assurance Requirements

1.0   GENERAL INFORMATION

This appendix is a supplement for guidance in tailoring the MIDEX Assurance Requirements. Henceforth, for sake of distinction, the "MIDEX Assurance Requirements" document will simply be referred to as the MAR. This appendix will be referred to as the Balloon SR & QA.

It is expected that the Principal Investigator will conform to the MAR document when addressing safety, reliability and quality using specific alternatives addressed in this appendix. The Explorer Program office also anticipates that a considerable amount of mission unique tailoring will be implemented when the MAR requirements are applied to balloon missions. It is not the purpose of this appendix to levy additional requirements on balloon missions but rather, to ensure those proposals for all types of missions have an equal opportunity to be selected.

It is understood that balloon missions differ significantly from low Earth orbit missions based on the environment and duration of a single flight and also the possibility of reflight. It is further recognized that significant differences will exist in needed environmental verification and qualification testing, as compared to longer duration orbital missions. It is the intent of the Explorer Program Office that MIDEX balloon missions will meet an adequate set of documented SR&QA requirements, to augment science derived engineering requirements, therefore increasing the likelihood of success. This will later be used as the baseline for measuring adequacy of the selected investigation's Phase-A effort with respect to mission assurance.

2.0   QUALITY ASSURANCE

2.1   Quality System

During Phase B, the PI must implement a quality system. It is desired, but not required, that this be based on ISO-9001. The system is to be documented in a quality manual and/or implementation plan. This quality system should be based on the flight duration (21 days for LDB flights), the flight environment and number of required re-flights.

2.2   Workmanship Standards

Same as the MAR.

2.3   Mission Assurance Audits and Reporting

Same as the MAR, Section 2.3. In addition, program management of NASA's Long Duration Balloon missions is performed by the Balloon Program Office (Code 820) located at the Wallops Flight Facility. Together with the National Scientific Balloon Facility (NSBF), who supports balloon launch and flight operations, the Balloon Program Office oversees certain audit and reporting functions which include but are not limited to:

- Completion of the NSBF LDB Flight Application.
- Establishing concise and achievable flight success criteria.
- Insuring gondola structural certification.
- Insuring thermal compatibility with NSBF flight systems.
- Insuring integration with NASA LDB flight support systems.
- Insuring LDB mission planning that is consistent with established operational and safety guidelines.
- Review of responses to actions assigned from reviews, as described in the following section.

3.0   REVIEWS

Same as the MAR, Section 3.0. A test plan is required in the Critical Design Review. Balloon missions could have elaborate re-flight or multiple flight plans. These must be reflected in the test plan.

In addition, the Balloon Program Office will conduct the following independent reviews. These reviews will be coordinated with the PI so that they can coincide with other reviews.

- Mission Initiation Conference (Semiformal) – This review will be conducted after submission of the NSBF LDB Flight Application. It will include the Principle Investigator's team and representatives from the Explorer Program Office, Balloon Program Office and the NSBF. Although the feasibility of each candidate mission's requirements will be reviewed prior to Phase-A, this *Mission Initiation Conference* will focus upon specific flight support requirements for the purpose of insuring assignments and tasks are properly assigned and being worked toward the program schedule requirements.

- Mission Readiness Review (Formal) – This review is conducted immediately after completion of integration and testing of the PI's gondola and instrumentation with the NSBF flight support systems. This is a balloon program review required by NASA HQ prior to shipment to the remote launch site. The purpose of this review is to assess the readiness of the integrated payload (this does not include a review of the merits of the science instrument or other MIDEX mandated conformance reviews.) This review will focus upon the readiness and completeness of the science instrument, flight support systems, ground support systems, and Mission & Operations plans. The objective at the time of this review

is that all systems be integrated, tested, and definitions / configurations / certifications are complete.

- Flight Readiness Review (Semiformal) – The Balloon Mission & Operations Management conducts this review at the launch site. The purpose of this review is to establish that all pre-flight readiness preparations are complete and to insure that both science and NSBF support personnel clearly understand the script for the launch, flight, and recovery operations.

- Post Flight Review (Semiformal) – This review is conducted by both the NSBF Mission & Operations Management and by the NASA Balloon Program Office. It will review all phases of the NSBF pre-flight support, launch, flight and recovery operations. Solicitation of PI comments and recommendations are the main focus of this review.

4.0   SAFETY

The PI is required to plan and implement a system safety program that identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of the mission development, launch, and operations. The program is to address hazards in the flight hardware, associated software, ground support equipment, and support facilities.

The PI team's system safety program must meet the system safety requirements stated in documents "NASA Balloon Program National Scientific Balloon Facility Payload Safety Process" and "NASA Balloon Program National Scientific Balloon Facility Ground Safety Plan." Balloon Flight Operations & Mission Safety is managed by the NASA Balloon Program Office, who will insure compliance in accordance with science mission objectives. These safety documents are available from Explorer Program Library.

5.0   DESIGN ASSURANCE

5.1   Electrical, Electromechanical, and Electronic (EEE) Parts

Same as the MAR, Section 5.1 with the following revision.

The Principal Investigator is required to implement an appropriate EEE parts program consistent with the proposed balloon mission concept for a Small Explorer mission. A LDB mission will typically be less than 21 days duration; however, the payload could be retrieved, refitted, and re-flown several times. Based on this, high quality commercial / industrial grade parts could be used on a balloon flight provided they are tested, inspected, properly stored and properly handled.

High voltage components must be operated through the entire pressure range, ground to float, to insure arcing does not cause latent damage or permanent failures. All parts should be life

tested based on mission duration and pressure, and thermally tested through the entire balloon environment range, ground to float. Balloon systems can potentially impose high static electricity buildup on the balloon and parachute. Balloon electronic support and instrumentation systems must incorporate proper grounding and shielding to mitigate risks associated with potential static discharges.

As a minimum, life cycle thermal testing should verify that all systems will continue to operate for the entire flight duration as bounded by nominal thermal hot and cold cases and thermal cycling. And demonstrate that all systems will recover and operate successfully after undergoing predicted thermal extreme hot and cold cases. Any operational mode that is tailored to accommodate any thermal operational limitation of the scientific instrument(s) must be indicated in the test plans and operations plans.

5.2   Materials

Same as the MAR, Section 5.2.

5.3   Reliability

Same as the MAR, Section 5.3 with the following amendments.

Balloon missions are unique in that payloads are normally recovered in such a condition that lends itself toward quick refurbishment and reflight. The Principal Investigator is encouraged to design the payload to survive landing and be capable of re-flight. As with any flight, there is always the risk of damage to the payload to such an extent as to make quick refurbishment impossible. To this extent, the Principle Investigator is encouraged to consider the availability of a backup payload or critical spares. By careful planning and by taking advantage of the multiple flight opportunities that may become available, for some instruments, LDB missions can offer an overall success rate that rivals that of expendable launch vehicles carrying space-rated instrumentation.

Balloon payloads do not experience the acoustics/vibration of a rocket launch and do not need to be designed or tested for these. Instead, LDB mission specific attributes that should be factored into every design are risks of high voltage arcing induced by a residual atmosphere environment, longer thermal dwell times (day / night / earth albedo), and survivability of mechanical shock loads during parachute opening and payload impact at the end of each flight. It is the Principal Investigator's responsibility to test for these.

5.3.1   Test Flight

Principle Investigators are encouraged to fly new balloon borne instruments on a short duration test flight for the purpose of verifying all elements of payload and mission operability. However, a short duration test flight is not a suitable substitute for thermal-vacuum qualification tests.

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Short test flights cannot be guaranteed to subject the payload to the environmental extremes that are likely to be encountered on a LDB mission.

5.3.2   Thermal Qualification

The Principal Investigator is required to provide a plan for implementing environmental testing that is appropriate to his/her mission. Thermal-vacuum testing must be conducted in such a manner as to demonstrate not only the thermal model, but also to provide system qualification. Thermal qualification testing for balloon missions can be more extreme than that required for ELV or NSTS systems because of the dwell times, albedo, etc. Balloons can be subject to several hours of daylight receiving direct solar and reflected (albedo) radiation. The night time environment can last several hours which includes not only cold sky, but also contribution from cold cloud tops, albedo, etc.

As part of Phase B, the Principle Investigator must provide a detailed thermal analysis. In turn, the NSBF's thermal analyst will use this information to insure close-coupled NSBF flight support systems are operating within proper limits and to insure the PI's instrument is not adversely affected by NSBF support systems. Principle Investigators are advised to schedule the services of a thermal analyst from the beginning through the final design configuration phase in order to be responsive to addressing configuration changes that might arise during the development, fabrication, and integration phases.

 Thermal "Worst Case" limits for nominal (operational limits) and maximum (survival limits) for articles exposed to both earth and sky are listed below. These are provided only to lend an appreciation for the possible extreme thermal environment that may be encountered. For example, cloud top temperatures for typhoons can expose the payload to –90C temperatures for a relatively short period. But the nominal cold extreme is –65C. Depending upon the terrain over which the balloon is flying, cold limits for any particular night may be warmer than those listed here. Conversely, high albedo during daytime can expose parts of the payload to +55C. But nominal upper limits are +40C or less. Passive and/or active thermal controls may be required in order to operate under these conditions.

- For articles exposed to external ambient

- Cold Case Temperatures: Operational down to –65C (nighttime)
                                   Survive down to –90C (2-hour duration)

- Hot Case Temperatures: Operational up to +40C (daytime)
                                   Survive up to +55C (2-hour duration)

- Unique Cases/Specialty Hardware

- Photo Voltaics (PV) should operate up to +75C and survive up to +90C. Higher ratings for photo voltaics are due to the solar orientation and the color/material absorptivity properties. Designs must account for thermal emissions off the backsides of PV cells. Similarly, any other unique material properties have to be evaluated on a per case basis as the above limits are stated only to provide for general planning consideration and not as absolute limits for all cases.

The balloon payload environment is close-coupled with earth albedo. Because of the wide latitude in payload geometry, attitude control, packaging, coatings, modes of operation, and various thermal control options, balloon payload designs must be tailored based upon each mission's requirements and constraints. For approved LDB missions, the NASA balloon program will assist with providing environmental data, for a particular flight scenario, for use in thermal analysis.

5.3.3   Random Vibration/Shock Tests

In flight, balloon payloads will not experience the vibration levels encountered on ELV or NSTS missions. However, Principle Investigators must provide documentation of test methods and results and/or inspections, practices and records, which clearly demonstrate the mechanical integrity of wiring, circuit boards, and mechanical assemblies. Essentially, this is a "proof of workmanship" verification. Low-level three-axis random vibration testing at sub-system levels may be considered as an acceptable means for verification. However, the Balloon Program Office imposes no standards for vibration testing.

Typically, prior to flight, the most severe mechanical shock loads experienced by balloon payloads are those encountered during shipment, particularly over-the-road. Along with overall payload design considerations, the PI must plan for proper shipping containers that will be accommodated by commercial carriers. Shipping includes over-the-road, sea, and turbo-prop air transport. Handling by NSBF at the launch site is normally a smooth transition from the payload preparation facility to the launch site. However, track-wheel vehicles are a mainstay support vehicle used with NSBF Antarctica flight operations.

At the end of the flight, shock loads associated with parachute opening and payload impact on the ground are the most severe mechanical loads associated with any balloon flight. The NSBF has established mechanical certification criteria, which is available as an appendix to the LDB Flight Application Form that can be obtained off the NSBF web site at http://master.nsbf.nasa.gov/pub/ldb-fy2000.pdf. This requirement stipulates a 10g structural loading requirement at the gondola vertical suspension point and 5g off-axis horizontal loading. Albeit these requirements are established for gondola structures, but when planning for the contingency of a quick turnaround of the payload for possible reflight, designers are advised not to reduce these load requirements when applying how they translate back into their design of internal component shock load integrity for such items as circuit boards, gimbal mountings, cable harnesses, connectors, etc.

5.4   Contamination

Same as the MAR, Section 5.4.

5.5   Software

Same as the MAR, Section 5.5.

6.0   VERIFICATION

The Principal Investigator is required to conduct a verification program to ensure that the gondola and instrument(s) meet the specific mission requirements.

The Principal Investigator is required to prepare and submit adequate verification documentation including a verification matrix, environmental test matrix and verification procedures to the Explorer Program Office for review.

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Part 2

MIDEX Assurance Guidelines

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MEDIUM EXPLORER (MIDEX) PROGRAM

MIDEX ASSURANCE GUIDELINES

Rev C

November 28, 1997

Approved by: Prepared by:

_____   _____
James S. Barrowman   Richard Claffy
Explorer Project Manager   Flight Assurance Manager

NASA Goddard Space Flight Center

Greenbelt, Maryland

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This MIDEX Assurance Guidelines (MAG) document provides guidelines and recommendations for elements of quality assurance that are important to consider in any space flight assurance program. These guidelines are provided to assist potential developers in estimating the cost of their expected assurance efforts and to assist development of their own Safety, Reliability and Quality Assurance (SR&QA) system.

This document also provides a basis and context for understanding any associated MIDEX requirements defined in Part 1, GSFC-410-MIDEX-002, "MIDEX Assurance Requirements (MAR)". The MAG and MAR are mission specific companion documents to be used in conjunction with the generic ANSI/ASQC 9001-1994 Quality Systems Model to provide a properly tailored, comprehensive SR&QA management system for MIDEX.

It is GSFC's experience that control of processes, intelligent selection of parts and materials, and thorough testing at all levels of assembly significantly increase the chance of success. Developers will be given significant flexibility in developing and tailoring their overall quality system, and should carefully consider the experience summarized by this document.

SECTION 1

OVERVIEW

1.1 OVERVIEW

Responsibility for implementation of the program defined in this document varies according to the mission implementation mode, i.e., NASA-provided spacecraft or Principal Investigator (PI) mode, and level of hardware provided (complete flight system, spacecraft, instrument, component, etc.). However, each MIDEX mission, spacecraft, and instrument hardware developer should plan and implement an organized Safety, Reliability and Quality Assurance (SR&QA) Program in accordance with the guidelines of this document that encompasses flight hardware, software, and ground support equipment.

In accordance with NASA Headquarters policies for Medium-class Explorers, a payload classification per NMI 8010.1A is not being used for MIDEX. This should permit tailoring of the SR&QA requirements to the ISO9001 series standards and any other mission assurance guidelines and requirements appropriate for the level of risk for a program of this scale.

1.2 USE OF MULTI-MISSION OR PREVIOUSLY DESIGNED, FABRICATED, OR FLOWN HARDWARE

Developers may choose to use previously designed, fabricated, or flown hardware without necessarily repeating all the tasks required for original qualification. Such hardware should have demonstrated compliance by way of previous flight or multi-mission history and should comply with the environmental requirements of the mission. Maintenance of original documentation is critical in the re-use of qualified hardware.

1.3 SR&QA VERIFICATION

It is recommended that the developer, together with GSFC, periodically validate the developer's overall SR&QA program. The intent of these validations should be to inform the developer, technical officer, Flight Systems Assurance Manager (FAMSAM), PI, and/or the project, of potential problems, questions, or concerns. If necessary, the developer, upon request, should provide GSFC or designated assurance representatives, with assurance and safety documents, and access needed to support these assurance and safety activities.

1.4 REFERENCED DOCUMENTS (Exhibit A)

Documents referred to in this guidelines package are summarized in Exhibit A, which also provides information on where the documents may be obtained. The listed documents are provided for guidance. The extent of applicability of each document is described in the associated paragraph(s) listed in Exhibit A.

1.5   GLOSSARY (Exhibit B)

Exhibit B defines terms used in this document.

SECTION 2

REVIEWS

2.1   GENERAL

The objectives of the MIDEX review program are to:

- assure that the spacecraft, instrument(s) and supporting designs are consistent with the mission objectives
- assure that the characteristics of the systems are carefully examined to develop the best approach consistent with existing constraints and available resources
- provide means of periodic evaluation of the hardware, software and ground support against mission criteria
- assure that end-item deliverables (systems and subsystems) meet the MIDEX requirements for performance, schedule and cost

Accordingly, the developer should plan and implement an appropriate review program. Refer to Part 1 for the MIDEX project requirements.

SECTION 3

VERIFICATION

3.1 GENERAL

A verification program should be conducted to ensure that the spacecraft, where produced separately from scientific instrument hardware (science payload), and the instruments themselves meet the specified mission requirements. The governing philosophy for MIDEX is that a complete and thorough verification program covering the component and assembly level is absolutely essential to achieving the compressed integration and test program needed to control cost and schedule, while providing confidence that all mission requirements have been met. The verification program should consist of a series of analyses, functional demonstrations, physical property measurements, alignments, calibrations, tests (performance and environmental), simulations, etc., that combine to demonstrate compliance with hardware/software engineering specifications derived from mission requirements.

3.2 ENVIRONMENTAL TEST PROGRAM

All flight hardware should be subjected to an environmental test program sufficient to demonstrate design qualification and to test for workmanship. Functional testing should be performed before, during, and after certain environmental tests, as appropriate.

The General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components (GEVS-SE) may be used as a guide for developing the environmental test portion of the verification program. Alternative methods that demonstrate compliance with mission requirements while integrating adequate safety margins could also be used.

Prototype and protoflight hardware should undergo appropriate qualification tests to demonstrate compliance with the design requirements. Flight, flight spare, follow-on, and re-flight hardware should undergo flight-like acceptance test levels.

The following tests are recommended as a baseline for MIDEX; specific requirements for each MIDEX spacecraft, instrument and component will be negotiated by the MIDEX Project at GSFC. Functional tests should be performed before, during, and after tests as appropriate.

Spacecraft

Strength (static or quasi-static), Low level (Pogo) Sine Vibration, Random Vibration, Acoustics, EMI/EMC, Thermal Vacuum/Thermal Balance, Mass Properties, Deployment (where applicable), Magnetics (where applicable). Accelerometers should be mounted on the hardware to document the vibration exposure experienced during test. Repeated functional tests should be used to demonstrate the growing maturity of spacecraft subsystems, and to baseline performance status before each environmental test. Several comprehensive

performance test demonstrations should be performed to verify full mission hardware compliance, compatibility, and operability.

Instruments and Components

Sine Vibration, Random Vibration, Strength, EMI/EMC, Thermal Vacuum/Thermal Balance, Mass Properties, Acoustics (where applicable), Deployment (where applicable), and Magnetics (where applicable). Functional tests are also considered a vital part of the verification program at these levels of assembly.

The GEVS-SE document described above is a useful guide for the design of these tests.

3.3 DEMONSTRATION OF FAILURE-FREE OPERATION

At the conclusion of the verification program, instruments and spacecraft components should have demonstrated a period of failure-free operation. This benchmark is usually 100 hours of failure free operation. The demonstration may be performed at the subsystem level when the time period of demonstration cannot be practically accomplished at the system level of assembly. Failure-free operation during the thermal-vacuum test is often included as part of the demonstration. Major hardware changes during or after the failure-free period are usually taken to invalidate any previous demonstration.

3.4 VERIFICATION DOCUMENTATION

Verification documentation should provide the following information:

- An overall verification approach
- Engineering requirements flowdown and basis for verification method (test or analysis)
- Tracking of accomplishments of tests and analyses against those planned
- Definition of specific environments for each test
- Advanced planning details of each test

Sections 3.4.1 through 3.4.4 describe the forms of documentation normally used to provide this information. Any proposed alternative form that provides this information should also be acceptable. Use of existing documentation practices or systems is encouraged.

3.4.1 Verification Matrix

The developer should have a verification matrix or equivalent system that shows the flowdown of requirements and the method of verification.

3.4.2 Environmental Test Matrix

The hardware developer should have an environmental test matrix or equivalent that summarizes all tests that will be performed, showing the test and the level of assembly. Tests on engineering models performed to satisfy qualification requirements should be included in this matrix. This matrix could be combined with the verification matrix on a common database.

The environmental test matrix should be current and should be available at the flight assurance and project reviews.

3.4.3   Environmental Verification Specification

A verification specification is normally prepared, to define the specific environmental parameters associated with the planned environmental tests. Payload peculiarities and interactions with the launch vehicle should be considered in defining these environmental parameters. These special interactions may include subjects like detuning of resonances, EMI/EMC effects, pyrotechnic firing disturbances, etc.

3.4.4   Verification Procedures

Detailed (step-by-step) verification procedures should be prepared for each test and analysis. The developer should maintain as-run verification procedures, as well as all test and analysis data.

SECTION 4

SYSTEM SAFETY

4.1   GENERAL

Launch sites require verification of compliance to specific safety requirements. Accordingly, the developer should plan and implement an appropriate system safety program. Refer to Part 1 for the MIDEX project requirements.

Section 5

Electrical, Electronic, and Electromechanical (EEE)

Parts Control

5.1   GENERAL

The selection and use of parts is a major contributor to the quality and reliability of space flight hardware. This section provides recommendations that, based on GSFC experience, are considered important for a good parts program. The developer should establish a parts program consistent with this section.

For effective use of parts information, it is strongly recommended that the developer use a qualified parts engineer, especially during those periods when designs are being developed and parts are being selected. Direct interaction with designers allows for effective use of judgment in considering known parts problems, parts failure modes, determining between commercial and special parts, parts availability, risks and benefits of new parts, screening, test, and burn-in methods, etc.

Review of the proposed parts with the Explorer Project at GSFC can make NASA experience available to the developer and so better ensure acceptability for space flight use.

5.2   EEE PARTS SELECTION

In general, all parts should be selected and processed in accordance with GSFC 311-INST-001, "Instructions for EEE Parts Selection, Screening, and Qualification" for Grade 3 quality level. As an additional aid in selecting parts for MIDEX hardware, the following guidelines are offered. Parts selected and procured as specified below are considered acceptable by the Explorer Project at GSFC.

   a.   Parts listed in the GSFC Preferred Parts List (PPL), or the NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List (NSPL), MIL-STD-975. Where differences in requirements exist between the PPL and the NSPL, the PPL should take precedence. Parts should be procured in accordance with the appropriate specification designated for that part.

   b.   MIL-M-38510, Class B or better microcircuits procured from a Qualified Products List (QPL) supplier. PIND testing is highly recommended.

   c.   MIL-I-38535, Class Q or better microcircuits procured from a Qualified Manufacturers' List (QML) supplier. PIND testing is highly recommended.

   d.   MIL-H-38534, Class H or better hybrid microcircuits procured from a Qualified Manufacturers' List (QML) supplier.

e. Standard Military Drawing (SMD) microcircuits procured from an authorized supplier as listed in the SMD. It is strongly recommended that microcircuits procured to SMD's be subjected to PIND testing in accordance with section 5.5.

f. Microcircuits compliant with paragraph 1.2.1 of MIL-STD-883 and procured from manufacturers having QPL or QML status for parts of the same technology. Parts procured from manufacturers without QPL or QML status should be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. MIL-STD-883 compliant microcircuits should be subjected to PIND testing in accordance with section 5.5.

g. Manufacturers' in-house high reliability processed parts provided all screening tests listed in Appendix C of the PPL have been satisfied. The high reliability process flow should be that formally documented by the manufacturer in cases where changes would require a revision to the flow documentation. Tests not included in the manufacturer's high reliability flow must be performed by the manufacturer, an independent test facility, or by the developer. Parts procured in this section should be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. If not included in the manufacturer's high reliability test flow, the parts should be subjected to PIND testing in accordance with section 5.5.

h. MIL-S-19500, JANTX, JANTXV and JANS semiconductors procured from a QPL listed supplier. It is preferred that semiconductors be procured to JANTXV level or better. Any semiconductor that has an internal cavity should be subjected to PIND testing in accordance with section 5.5.

i. Established Reliability (ER) passive components procured from a QPL listed supplier for the appropriate military specification. Only ER parts within the minimum and maximum value ranges specified in the PPL should be considered acceptable.

j. Parts procured to a GSFC S-311 specification from a GSFC approved source.

5.2.1   EEE PARTS IDENTIFICATION LIST (PIL)

The developer in accordance with the developer's configuration control system should maintain an EEE Parts Identification List (PIL). Maintenance of this list in a computer compatible form is recommended.

The PIL normally is compiled by component and includes information such as: part number, part name, manufacturer, manufacturer's generic part number, specifications, quantities, lot date code, and part use locations to the subassembly level.

5.3   OTHER PARTS

Any parts not meeting the criteria specified in section 5.2 should be selected and controlled in accordance with sections 5.3.1 through 5.3.5.

5.3.1   EEE Parts Control and Approval

The developer should document the selection, application, evaluation, and acceptance of parts selected from other than the sources defined in section 5.2. The use of a developer parts control board is recommended as a mechanism to document and accomplish parts selection, acceptance, qualification, etc.

5.3.1.1 EEE Parts Specifications

Developer controlled procurement and screening specifications should be prepared for all parts in this category. These specifications should fully identify the item being procured and should include physical, electrical, and environmental test requirements and quality assurance provisions necessary to control manufacture and acceptance. Screening requirements designated for the part can be included in the procurement specification. They should specify test conditions, failure criteria, and lot rejection criteria. For lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot should be in accordance with that prescribed in the closest military part specification.

5.3.2   EEE Parts Screening

All parts selected should receive 100 percent screening in accordance with GSFC 311-INST-001, "Instructions for EEE Parts Selection, Screening and Qualification". The Grade 3 quality level should apply. Parts selected in accordance with 5.2 herein are considered to have met the requirements of 311-INST-001, except for PIND testing which is strongly recommended as specified above. The developer need not repeat tests performed by the manufacturer. If parts are not procured by government controlled specifications, the required screening should be specified in the developer's Source Control Drawings used to procure the parts to assure testing is performed by the parts manufacturers. Otherwise, the developer should arrange for the appropriate screens to be performed after receipt of the parts.

5.3.3   EEE Part Qualification

Qualification testing should not be required unless deemed necessary as a result of part failure history, GIDEP Alerts, or a new technology part with no flight history. If needed, the primary part qualification should consist of either the manufacturer's lot specific or generic QCI test data within one year of the lot date code of the procured parts. The test data should be procured with the parts and reviewed for acceptability by the developer. If QCI data is not available, a

lot specific steady state life test in accordance with MIL-STD-883, Method 5005 should be performed. The minimum sample size for life testing should be 12 pieces.

5.3.4   Hybrid Microcircuits

Hybrid microcircuits should be designed and procured in accordance with MIL-H-38534, Level H. Any hybrid not fully conforming to MIL-H-38534 should receive Destructive Physical Analysis (DPA) in accordance with section 5.4.

5.3.5   Magnetic Devices

Selection and approval of magnetic devices should be in accordance with the applicable military specification. Materials used in the manufacture of magnetic devices should be consistent with any program requirements for outgassing.

5.4   DESTRUCTIVE PHYSICAL ANALYSIS (DPA)

Except as otherwise specified in section 5.3.2, a DPA should not be required unless it is deemed necessary as indicated by failure history, GIDEP Alerts, or other similar concerns. If DPA is needed, GSFC S-311-M-70, Destructive Physical Analysis Procedures can be used to define DPA tests, procedures, sample sizes, and acceptance criteria.

5.5   PARTICLE IMPACT NOISE DETECTION (PIND) TEST

It is strongly recommended that all microcircuits and semiconductors with an internal cavity and a package style other than ceramic dual in line packages be subjected to PIND testing in accordance with 311-INST-001. PIND testing should be performed by the manufacturer as part of the screening flow or by the developer after receipt of the parts. Lot jeopardy is not recommended. However, any lot exceeding 25 percent PIND failures should receive particle capture and analysis to identify the particles' conductive properties. Acceptance or rejection of these lots should be based on the result of the analysis

5.6   DERATING

All parts should be used in accordance with the derating guidelines specified in GSFC PPL, Appendix B or equivalent developer procedures.

5.7   PARTS AGE CONTROL

Parts drawn from controlled storage more than 7 years after the last full screen should be subjected to a full rescreen and sample DPA. (For increased reliability, GSFC normally rescreens parts after 5 years of storage.) Reduced testing such as Product Verification Testing (PVT) or sample screening could be performed instead if it is deemed adequate for the particular part type. Parts stored in uncontrolled conditions where they were exposed to the elements or sources of contamination should not be used.

5.8   RADIATION HARDNESS

All parts should be selected to meet the mission application in the predicted radiation environment. The radiation environment consists of two separate effects, those of Total Ionizing Dose (TID) and Single Event Effects (SEE). Each part should be analyzed with respect to both of these effects. Additional radiation testing is sometimes necessary to properly qualify parts. The Explorer Project at GSFC can offer to any MIDEX participant the benefit of cumulative parts radiation testing database information, as well as assistance in predicting radiation severity, for parts selection purposes, of selected or candidate orbital geometries.

5.9   ALERTS

The Explorer Project at GSFC can provide the developer with selected Government Industry Data Exchange Program (GIDEP) Alerts and Safe-Alerts that document problems with parts, materials, processes and safety. Typically, these alerts deal with specific vendors, model/part ID numbers, date codes, and serial numbers. This is a fundamental reason that Parts Identification Lists (PILs) are strongly recommended, and that the level of configuration detail is critical. With this information, it can be immediately determined whether an alert is applicable to MIDEX, or more commonly, provide confidence that it is not.

SECTION 6

MATERIALS AND PROCESSES

6.1   GENERAL

The developer should implement a Materials and Processes (M&P) Program beginning at the design stage of the hardware. The program can help ensure the safety and success of the mission by the appropriate selection, processing, inspection, and testing of the materials employed to meet the operational requirements for MIDEX.

Review of the proposed materials and processes with the Explorer Project at GSFC can make NASA experience available to the developer and so better ensure acceptability for space flight use.

6.2   MATERIALS SELECTION

In order to anticipate and minimize materials problems during hardware development and operation, the developer, when selecting materials, should consider potential problem areas. Some of these are radiation effects, thermal cycling, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled surfaces, composite materials, atomic oxygen, useful life, vacuum outgassing, toxic offgassing, flammability and fracture toughness. Specific selection guidelines are discussed below.

6.2.1   Inorganic and Metallic Materials

The criteria specified in MSFC-SPEC-522B can be used to determine that metallic materials meet stress corrosion cracking criteria. Table I materials are strongly preferred. The proposed use of Table II and Table III materials should receive careful consideration and should be discussed with the Explorer Project at GSFC.

6.2.2   Polymeric Materials

Because of low temperature related damage concerns during test and on-orbit operation, it is strongly recommended that Uralane products be used for conformal coating applications instead of Solithane. Uralane does not experience glass transition at common operating temperatures so it does not unduly stress the materials it coats in the way that Solithane can.

6.2.3   Lubrication

Lubricants should be selected for use on the basis of the specific application, including compatibility with the anticipated environment and contamination effects. NASA TM 82275 and 82276 are available for guidance in selecting lubricants and ball bearings.

6.2.4   Flammability

Consideration of material flammability should be a criterion for materials selection. **(For Space Shuttle payloads the consideration of material flammability is mandatory.)** GSFC

materials flammability database information and consultation will be provided on request. The chief focus on flammability as a materials consideration should be on external and uncontained surfaces such as blankets or coverings (base material plus coating materials combined behavior) and their relative proximity to possible ignition sources of either electrical, chemical, or mechanical origin.

6.2.5 Vacuum Outgassing

If material vacuum outgassing data is needed, it should be determined by testing in accordance with ASTM E-595 to ensure compatibility with other spaceflight evaluation data bases. In general, a material is qualified on a product-by-product basis. Lot testing may be appropriate for any material for which lot variation is suspected. Normally, only materials that meet the criteria of ASTM E-595 [i.e., have a total mass loss (TML) <1.00 percent and a collected volatile condensable mass (CVCM) <0.10 percent] are used for space systems unless application considerations dictate otherwise. These levels should serve as the baseline for MIDEX; however, mission specific targets should be established when actual system architectures are better defined. Information on many materials is available in "Outgassing Data for Selecting Spacecraft Materials," NASA Reference Publication 1124, Rev 3, Goddard Space Flight Center, Greenbelt, Maryland, November 1993.

6.2.6 Shelf-Life-Limited Materials

Polymeric materials that have a limited shelf-life should be controlled to prevent use beyond expiration dates. Important items include the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints should be included. The use of materials whose date code has expired usually requires demonstration by means of appropriate tests that the properties of the materials have not been compromised for their intended use. When a limited-life piece part is installed in a subassembly, the subassembly item should be included in the Limited-Life List, section 7.4.

6.2.7 Fasteners

To limit potential fastener problems, especially in critical areas, the developer should comply with the procurement documentation and independent test requirements for flight hardware and critical ground support equipment fasteners contained in GSFC S-313-100, "Goddard Space Flight Center Fastener Integrity Requirements" or equivalent measures described in developer internal documentation:

> In general, single point failure fasteners should be obtained from GSFC approved manufacturers and with the manufacturer's material test reports; be 5mm in diameter or larger, and be subjected to screening tests independent of the manufacturer (visual, tensile, 100 percent NDE, 100 percent hardness, and 100 percent dimensional)

Redundant load path fasteners 5mm in diameter or larger can be procured from any responsible manufacturer or distributor with the manufacturer's material test reports. These fasteners should be subjected to independent lot sample screening tests (visual, tensile, and dimensional)

Fasteners less than 5mm in diameter need no manufacturer's test reports and need only be independently screened for visual defects.

Refer to S-313-100 for specific details including those for rivets and other special fasteners.

Fasteners made of plain carbon or low alloy steel should be protected from corrosion. When plating is specified, it should be compatible with the space environment. On steels harder than RC 33, plating should be applied by a process that is not embrittling to the steel.

6.3   PROCESS SELECTION

Manufacturing processes (e.g., lubrication, heat treatment, welding, chemical or metallic coatings), should be carefully selected to prevent any unacceptable material property changes that could cause adverse effects on materials applications.

6.4   PROCUREMENT

6.4.1   Purchased Raw Materials

Each lot of raw materials purchased by the developer should be accompanied by the results of nondestructive chemical and physical tests specific to the lot. The developer should maintain these data.

6.4.2   Raw Materials Used in Purchased Products

The developer should require that the supplier meet the recommendations of section 6.4.1 and provide, on request, the results of acceptance tests and analyses performed on raw materials.

6.5   GIDEP ALERTS

The developer should keep materials selection and usage records sufficient to determine applicability of any Government Industry Data Exchange Program (GIDEP) alerts related to materials used for MIDEX.

6.6   MATERIALS AND PROCESS LISTS

The developer should maintain lists of inorganic and metallic materials, polymeric materials, lubricants, and processes to be used for MIDEX. The equivalent GSFC forms 18-59A, B, C, and D define information considered important. The developer may wish to have one master materials usage list to include this information. It is recommended that the list(s) be maintained in a computer compatible form.

SECTION 7

DESIGN ASSURANCE AND RELIABILITY

7.1   GENERAL

The developer should include reliability considerations as part of the design process. This should begin at the earliest stages of the program.

7.2   DESIGN TRADEOFFS

Design tradeoffs should address reliability considerations, including evaluation of alternative designs, functional redundancy, etc.

Absolute system or component reliability estimates may not be needed for MIDEX. However, in evaluating the reliability of two or more competitive system level designs, a comparison of the relative numerical reliabilities, derived using consistent methodology and data, is highly recommended for internal use. Consistent methodology and data should be used so that the relative magnitudes of each result can be compared.

7.3   RELIABILITY CONCERNS AND MITIGATIONS

Early in the program, the developer should identify specific reliability concerns and the steps being taken to mitigate them. The analysis of likely failure modes may not be needed. As a minimum analysis effort, the Developer should conduct a Failure Modes and Effects Analysis (FMEA) at the interface level between the instrument and spacecraft. The Developer may, if necessary, seek assistance from the MIDEX Project.

7.4   LIMITED LIFE ITEMS

Limited life items should be identified on a limited life list. The list should include the expected life and the rationale for the selection of each item. Limited life items include all hardware that is subject to degradation due to age, operating time, or cycles, such that its expected useful life is less than twice the required life, when fabrication, test, storage, and mission operation are combined. The developer should maintain a record of total operating times for these items.

SECTION 8

QUALITY ASSURANCE

8.1   GENERAL

For past Explorer missions, the Project Office at GSFC has always identified detailed quality system (SPAR, PAR) requirements and specified precisely how they were to be accomplished. In an effort to remove non-value-added requirements, and to emphasize the use of existing commercial practices and standards, NASA has committed to transitioning its quality assurance policy to align with the International Organization for Standardization (ISO) 9000 standards. These standards provide a good checklist of what is needed for a quality program, but allow significant flexibility to the developer in determining which requirements actually apply and how they are implemented. This allows for the use of a single generic quality system at a university or commercial firm that is not specifically or exclusively tied to the Explorer Project at GSFC.

This approach, combining developer flexibility and responsibility, is considered appropriate for the kind of teaming efforts that will be formed for MIDEX. It also puts the NASA and university communities in step with internationally accepted methods of quality management, which will facilitate future commerce in the aerospace industry for NASA and PIs. Eventually, visible and tangible compliance with ISO 9000 standards will become a prerequisite for entry into the competitive market place.

Accordingly, the baseline quality system for MIDEX should be the United States implementation of ISO 9000 as defined by ANSI/ASQC Q9001-1994. It is intended that this will allow the developer greater control over the quality system and the ability to concentrate on value-added quality activities.

As part of Phase B activities, the developer should define and implement a quality system, based on ANSI/ASQC Q9001-1994 that properly encompasses MIDEX flight hardware and software. Complete and immediate compliance with this standard may not be possible, but a workable system created along these lines is important.

8.2   QUALITY MANUAL

To facilitate development or definition of the quality system, a Quality Manual should be completed during Phase B. This should be a brief, top-level management system document that includes the following:

1) Introduction (title, scope, table of contents, and organization introduction).
2) The quality policy and objectives of the organization.
3) Description of the organization, responsibilities, and authorities (with or without a flowchart).
4) A description of the elements of the quality system.

If requested, The Explorer Project at GSFC can provide informal working level assistance for interpreting the ANSI/ASQC Q9001-1994 requirements for MIDEX and for development of the Quality Manual.

8.3   QA SYSTEM AUGMENTATION

8.3.1   Workmanship Standards

Paragraph 4.9, Process Control of ANSI/ASQC Q9001-1994, should be augmented to include the use of several commercial specifications and NASA handbooks, as appropriate, in procurement and fabrication activities. These documents define appropriate workmanship standards:

ANSI/J-STD-001 (or NHB 5300.4(3A-2)) for high reliability soldering of electrical connections. This should include the applicable standards ANSI/J-STD-002 through -006 as needed

NHB 5300.4(3G) for interconnecting cables, harnesses, and wiring

NHB 5300.4(3H) for crimping

NHB 5300.4(3J) for conformal coating and staking

IPC-D-275 (or NHB 5300.4(3K)) for design of printed wiring boards and assemblies

EIA-625 (or NHB 5300.4(3L)) for ESD control

In addition, printed wiring boards should be procured and fabricated in accordance with ANSI/IPC RB276 (Class 3) and GSFC S-312-P-003. Printed wiring board coupons should be provided to the Explorer Project at GSFC, or to a GSFC approved laboratory, for evaluation. In either case, the specimen preparation (potting, polishing, baking, etc.) should be done in accordance with GSFC practice guidelines. Evaluation results should be based on a conservative interpretation of ANSI/IPC RB276 (Class 3) and GSFC S-312-P-003 acceptance criteria. The basis for this recommendation is that past and present GSFC missions have experienced a significant pattern of bare printed wiring board internal trace to barrel plating bond failures, too often uncovered after population with flight parts, usually during component/system level environmental testing or during integration and test. These defects are readily detected and screened out at the bare board level, where the cost and schedule impact is minimal. As such, no boards should be populated prior to completion of the coupon tests. Schedules should allow for time, generally 2-3 weeks, to accomplish these evaluations.

8.3.2   Failures

Paragraph 4.13.2 of ANSI/ASQC Q9001-1994 should be augmented to define failure reporting system needs.

Any departure, or suspected departure, from design, performance, testing, or handling requirements that affects the function of flight equipment should be immediately documented. Failures in ground support equipment which interfaces with flight equipment as well as any other malfunction that could compromise mission objectives should be immediately documented.

Failures (departures from requirements discovered in the functioning or operating of hardware or software) should be documented. Formal, internal reporting of failures should begin with the first power application at the lowest level of assembly or the first operation of a mechanical item. Failures should be reported to the Explorer Project at GSFC as required by the MIDEX Project Office.

8.4   REWORK

The possibility of adverse effects on hardware and reliability should be considered prior to initiating any rework efforts. For example, case by case reviews of solder connections have demonstrated that rework solely for cosmetic reasons is frequently counter productive.

SECTION 9

CONTAMINATION CONTROL

9.1   GENERAL

The contamination requirements baseline for MIDEX should be taken to be that systems will be assembled in clean and orderly work areas, normally defined as class 300,000 areas, unless more stringent requirements are needed and identified. (Space Shuttle Payloads may have more stringent requirements imposed upon them.)

The developer should identify contamination requirements and establish and maintain a contamination control program consistent with these and mission requirements. Contaminants are defined as those materials, either at a molecular or particulate level, whose presence degrades mission performance. The source of these contaminants may be the hardware itself, the test facilities, or the environments to which the hardware is exposed.

It is suggested that the developer's program first define the specific cleanliness requirements needed and then set forth the approaches to meeting them. The program should then implement the control and monitoring activities specified by the approaches. The program should be documented by a Contamination Control Plan (CCP), or other equivalent means.

9.2   CONTAMINATION ALLOWANCE OR TARGET

As a basis for contamination control activities, the developer should establish a contamination allowance, or target, for performance degradation of any contamination-sensitive hardware such that, even in the degraded state, the hardware will meet an acceptable level of its mission objectives. The contamination allowances should be established initially, to the extent possible, during the early design phase in preparation for the PDR and should be updated as needed.

9.3   CONTAMINATION CONTROL

The developer should delineate the measures to be taken to ensure that the contamination allowances established under section 9.2 are not exceeded. These measures could include inspections, tests, and analyses (including associated implementing and controlling documentation) for measuring and maintaining the levels of cleanliness required during the various phases of the hardware life.

The developer should identify contamination controls to be exercised during applicable bake-outs and in the preparation of the thermal-vacuum chamber and the necessary fixtures and stimuli for system-level tests. Operational procedures that will be followed to minimize the potential contamination hazard from pumpdown through return to ambient conditions should also be identified. In cases where localized hardware contamination protection is needed, a practical solution may be a dry gas purge.

Because they can be a source of contamination themselves, special consideration should be given to materials and equipment used in cleaning, handling, testing, packaging, and bagging (e.g., antistatic film materials).

Contamination Control

SECTION 10

SOFTWARE DEVELOPMENT

10.1   GENERAL

The developer should employ a structured program for the development of software. The program should recognize the phases of the development life cycle (requirements analysis, design, code and unit test, integration and build test, performance verification, and maintenance) and utilize appropriate mechanisms to facilitate the development effort and ensure the quality of the product. These mechanisms include documentation, reviews, verification activities, and configuration management. The program should encompass instrument flight software and firmware, ground test equipment software, and any software related to mission operations. Science and data analysis software are normally excluded from these requirements.

10.2   SOFTWARE DOCUMENTATION

The developer should establish and document software requirements and, where appropriate, external interface specifications and users' guides. Design documentation should also be prepared, but this documentation may be less formal and internally controlled. The developer should establish and document its software verification program as discussed in Section 10.4 below.

10.3   SOFTWARE REVIEWS

The developer should participate in a program of internal and external software reviews designed to validate the software requirements, design and operating characteristics, verify external interface requirements, and produce structured, error-free, maintainable code.

The developer should prepare for and participate in any project-level Software Requirements or design reviews. The complexity and criticality of the software and the extent of its external interfaces should determine the extent and formality of the reviews. For example, the requirements review could range from circulation of a document for comments to a formal presentation.

The developer should establish a program of internal reviews designed to verify adherence to development standards and design guidelines, testing adequacy, and to verify whether the design satisfies the requirements. These internal reviews should consist of status and technical reviews, including design and code walkthrough peer reviews.

Software requirements, design, management, and developmental status should be included as part of any GSFC formal design reviews.

10.4   PERFORMANCE VERIFICATION

The developer should conduct a software test program to demonstrate the performance adequacy of the software. This program should encompass testing at the build or release level, and system-level testing of the product. The verification documentation should include test plans

and procedures, and a Software Test Matrix, or equivalent document(s) that show(s) the software requirements, tests to be run to satisfy the requirements, and results.

10.5   CONFIGURATION MANAGEMENT

The developer should employ a software configuration management process to manage requirements, code, documentation, and data, and to track and report on the status of changes to them. The process should include a means to record, track and disposition identified discrepancies in the product (i.e., non-conformance control). The process should also include a mechanism for referring to the project for approval of any change requests that will affect schedule, cost, function, or external interfaces.

EXHIBIT A: APPLICABLE DOCUMENTS

PARAGRAPH NO.	DOCUMENT NO.	TITLE	AVAILABLE FROM
		SECTION 3	
3.2	GEVS-SE	General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components (January 1990)	Note 5
		SECTION 5	
5.2; 5.3.2; 5.5	GSFC 311-INST-001	Instructions for EEE Parts Selection, Screening, and Qualification	Note 5
5.2; 5.6	GSFC PPL 20	GSFC Preferred Parts List	Note 5
5.2	MIL-STD-975	NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List	Note 1, 3 or 5
5.2	MIL-M-38510	General Specification for Microcircuits	Note 3
5.2	MIL-I-38535	General Specification for Integrated Circuits (Microcircuits) Manufacturing	Note 3
5.2; 5.3.4	MIL-H-38534	General Specification for Hybrid Microcircuits	Note 3
5.2; 5.3.3	MIL-STD-883	Test Methods and Procedures for Microelectronics	Note 3
5.2	MIL-S-19500	General Specification for	Note 3

Semiconductor Devices

| 5.4 | GSFC S-311-M-70 | Specification for Destructive Physical Analysis (DPA) | Note 5 |

SECTION 6

6.2.1	MSFC-SPEC-522B	Design Criteria for Controlling Stress Corrosion Cracking	Note 1, 3 or 6
6.2.3	NASA-TM 82275 (GSFC Mtr. No. 313-003) *-81N71132	An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications	Note 2
6.2.3	NASA-TM 82276 (GSFC Mtr. No. 755-013) *-81N71205	Quality Features of Spacecraft Ball Bearing Systems	Note 2
6.2.5	ASTM E-595	Standard Test Methods for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment.	Note 9
6.2.5	NASA RP-1124 *-94N21889	Outgassing Data for Selecting Spacecraft Materials	Note 2
6.2.7	GSFC S-313-100	Goddard Space Flight Center Fastener Integrity Requirements	Note 5

SECTION 8

8.1; 8.2; 8.3.1; 8.3.2	ANSI/ASQC Q9001-1994	Quality Systems-Model for Quality Assurance in Design, Development, Production, Installation, and Servicing	Note 5, 10 or 11
8.3.1	NHB 5300.4 (3A-2) *-93N12674	Requirements for Soldered Electrical Connections	Note 2, 5 or 8
8.3.1	NHB 5300.4 (3G) *-85N72711	Requirements for Inter-connecting Cables, Harnesses, and Wiring	Note 2, 5 or 8

| 8.3.1 | NHB 5300.4 (3H) *-94N71048 | Requirements for Crimping and Wire Wrap | Note 2, 5 or 8 |
| 8.3.1 | NHB 5300.4 (3J) *-94N71696 | Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies | Note 2, 5 or 8 |

8.3.1	NHB 5300.4 (3K) *-86N27577	Design Requirements for Rigid Printed Wiring Boards and Assemblies	Note 2, 5 or 8
8.3.1	NHB 5300.4 (3L)	Requirements for Electrostatic Discharge Control	Note 2 or 5
8.3.1	GSFC S-312-P-003	Procedure Specification for Rigid Printed Boards for Space Applications and other High Reliability Uses	Note 5
8.3.1	ANSI/J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies	Note 12
8.3.1	ANSI/J-STD-002	Solderability Tests for Component Leads, Terminations, Lugs, Terminals, and Wires	Note 12
8.3.1	ANSI/J-STD-003	Solderability Tests for Printed Boards	Note 12
8.3.1	ANSI/J-STD-004	Requirements for Solder Fluxes	Note 12
8.3.1	ANSI/J-STD-005	Requirements and Test Methods for Solder Paste	Note 12
8.3.1	ANSI/J-STD-006	Requirements for Solder Alloys	Note 12
8.3.1	ANSI/IPC RB276	Qualification and Performance Specification for Rigid and Printed Boards	Note 12

NOTES (SOURCES):

1 -- Superintendent of Documents, U.S. Government Printing Office, Washington, DC, 20402

2 -- NASA Scientific and Technical Information Facility, P.O. Box 8757, BWI Airport, Maryland, 21240

3 -- Department of the Navy, Naval Publications & Forms Center, 5801 Tabor Avenue, Philadelphia, PA, 19120

4 -- NASA/Lyndon B. Johnson Space Center, Publication Control Office, Houston, TX, 77058

5 -- NASA, MIDEX Project Office, Code 410, Goddard Space Flight Center, Greenbelt, MD, 20771

6 -- NASA/Marshall Space Flight Center, Marshall Documentation, Huntsville, AL, 35812

7 -- National Technical Information Service, Springfield, VA, 22161

8 -- NASA Information Center, Code DB-4, NASA Headquarters, Washington, D.C. 20546 Phone
(202) 453-1000)

9 -- American Society for Testing & Materials (ASTM), 1916 Race St., Philadelphia, PA. 19103-
1187

10-- American Society for Quality Control (ASQC), 611 East Wisconsin Ave., Milwaukee, WI.
53202-4606

11-- American National Standards Institute (ANSI), 11W. 42nd St., 13th Floor, New York, NY.
10036

12-- Institute for Interconnecting and Packaging Electronic Circuits, 7380 N. Lincoln Ave.,
Lincolnwood, IL. 60646

*-NASA STI (Note 2) Recon Number: can be ordered individually from NASA STI by these
numbers.

EXHIBIT B
GLOSSARY

EXHIBIT B: GLOSSARY

Acceptance Test: The process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and is normally used to provide the basis for delivery for an item under terms of a contract.

Assembly: A functional subdivision of a component, consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and a gyroscope.

Audit: A review of the contractor's or subcontractor's documentation or hardware to verify that it complies with project requirements.

Critical: A potential failure effect which would result in a significant (as defined by the project) performance degradation of an item of hardware or a mission.

Collected Volatile Condensable Material (CVCM): The quantity of outgassed matter from a test specimen that condenses on a collector maintained at a specific constant temperature for a specified time.

Component: A functional subdivision of a subsystem, generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are transmitters, gyro packages, actuators, motors, batteries.

Configuration: The functional and physical characteristics of parts, assemblies, equipment of systems, or any combination of these which are capable of fulfilling the fit, form and functional requirements defined by performance specifications and engineering drawings.

Configuration Management: The systematic control and evaluation of all changes to baseline documentation and subsequent changes to that documentation which define the original scope of effort to be accomplished (contract and reference documentation) and the systematic control, identification, status accounting, and verification of all configuration items.

Derating: The reduction of the rating of a device to improve reliability or to permit operation at high ambient temperatures.

Designated Representative: An individual (such as a NASA plant representative), firm (such as an assessment contractor), Department of Defense (DOD) plant representative, or other government representative designated and authorized by NASA to perform a specific function of NASA. As related to the contractor's effort, this may include evaluation, assessment, design review participation, and review/approval of certain documents or actions.

Destructive Physical Analysis (DPA): An internal destructive examination of a finished part or device to assess design, workmanship, assembly, and any other processing associated with fabrication of the part.

Electromagnetic Compatibility (EMC): The condition that prevails when various electronic devices are performing their functions according to design in a common electromagnetic environment.

Electromagnetic Interference (EMI): Electromagnetic energy that interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment.

Failure: See Nonconformance.

Failure Modes, Effects Analysis (FMEA): The study of a system and working interrelationships or its elements to determine ways in which failures can occur (failure modes),and effects of each potential failure on the system element in which it occurs.

Functional Tests: The operation of a unit in accordance with a defined operational procedure to determine whether performance is within the specified requirements.

Hardware: Physical items of equipment. As used in this document, there are two major categories of hardware as follows:

> 1. Non Flight Hardware: Development hardware not intended to fly, or hardware of flight design but found to be of unsuitable quality for flight use, or hardware intended for use on the ground.
>
>   a. Prototype Hardware: Hardware of a new design that is subject to a design qualification test program, but is not intended for flight.
>
> 2. Flight Hardware: Hardware to be used operationally in space. It includes flight instruments (experiments) and/or spacecraft hardware.
>
>   a. Protoflight Hardware: Flight hardware of a new design that is subject to a test program, by exposure to design qualification levels and durations equivalent to a flight acceptance test program.
>
>   b. Follow-On Hardware: Flight hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to a flight acceptance test program.
>
>   c. Space Hardware: Hardware that has been proven in a design qualification test program and that is subject to a flight acceptance test

program and that is used to replace flight hardware which is no longer acceptable for flight.

    d. Reflight Hardware: Flight hardware that has been used operationally in space and is to be reused in the same way; the verification program to which it is subject depends on its past performance, current status, and the upcoming mission.

Inspection: The process of measuring, examining, gauging, or otherwise comparing an article or service with specified requirements.

Instrument: A subsystem consisting of sensors and associated hardware for making measurements or observations in space. The flying portion of a flight experiment.

Margin: The amount by which hardware capability exceeds requirements.

Monitor: To keep track of the progress of a performance assurance activity. The person monitoring need not be present at the scene during the entire course of the activity, but will review resulting data or other associated documentation (see Witness).

Nonconformance: A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. As applied in quality assurance, nonconformances fall into two categories -- discrepancies and failures. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Part: A hardware element that is not normally subject to further subdivision or disassembly without destruction of designed use. Examples are bolts, diodes, resistors, etc.

Performance Verification: Determination by test, analysis, or a combination of the two that the spacecraft can operate as intended in a particular mission. This includes being satisfied that the design of the spacecraft or element has been qualified and that the particular item has been accepted as true to the design and ready for flight operations.

Qualification: The process of demonstrating that a given design and manufacturing approach will produce hardware that will meet all performance specifications when subjected to defined conditions more severe than those expected to occur during its intended use.

Redundancy (of design):   The use of more than one independent means of accomplishing a given function.

Repair: The article is to be modified by established (customer approved where required) standard repairs or specific repair instructions which are designed to make the article suitable for use, but which will result in a departure from the original specification.

Rework: Return for completion of operations per drawing. The article is to be reprocessed to conform to the original specifications or drawings.

Single Point Failure: A single element of hardware, which if it fails, would result in the loss of mission objectives or the hardware, as defined for the specific application or project for which a single point failure analysis is performed.

Spacecraft: An integrated assemblage of subsystems designed to perform a specified mission in space.

Subassembly: A subdivision of an assembly. Examples are wire harnesses and populated printed circuit boards.

Subsystem: A functional subdivision of a spacecraft consisting of two or more components. Examples are attitude control, electrical power subsystems, and instruments.

Thermal Balance Test: A test conducted to verify the adequacy of the thermal design and the capability of the thermal control system to maintain thermal conditions within established mission limits.

Total Mass Loss (TML): Total mass of material outgassed from a specimen that is maintained at a specified constant temperature and operating pressure for a specified time.

Verification: See Performance Verification.

Vibroacoustics: An environment induced by high-intensity acoustic noise associated with various segments of the flight profile, it manifests itself throughout the payload in the form of directly transmitted acoustic excitation and as structure-borne random vibration excitation.

Witness: A personal, on-the-scene observation of a performance assurance activity with the purpose of verifying compliance with project requirements. (see Monitor).

Common Terms not included in MAG:

Catastrophic: A potential failure effect that would result in complete loss of an item of hardware or a mission or result in serious injury to personnel. e.g., loss of ability to recover science data would be catastrophic to an instrument mission.

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes and the implementation of all approved changes to the design and production of an item, the configuration of which has been formally approved by the contractor or by the purchaser, or both.

Design Specification: Generic designation for a specification which describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements. The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects the end-item specifications serve all the purposes of design specifications for the contract and items. Design specifications provide the basis for technical and engineering management control.

Discrepancy: See Nonconformance.

Effectivity: The point (in configuration evolution) at which a change or action becomes applicable to the hardware or software.

Electromagnetic Susceptibility: Undesired response by a component, subsystem, or system to conducted or radiated electromagnetic emissions.

End-to-End Tests: Tests performed on the integrated ground and flight system, including all elements of the payload, its control, communications, and data processing to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Similarity, Verification By: A procedure of comparing an item verified. Configuration, test data, application and environment should be evaluated. It should be determined that design differences are insignificant, environmental stress will not be greater in the new application, and that manufacturer and manufacturing methods are the same.

Temperature Cycle: A transition from some initial temperature condition to temperature stabilization at one extreme and then to temperature stabilization at the opposite extreme and returning to the initial temperature condition.

Temperature Stabilization: The condition that exists when the rate of change of temperatures has decreased to the point where the test item may be expected to remain

within the specified test tolerance for the necessary duration or where further change is considered acceptable.